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Variations of Air Temperature and Canopy Closure in a Lodgepole Pine Stand

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Vertical air temperature profiles were measured under various degrees of canopy closure in a lodgepole pine stand. The air temperatures were scaled by the temperature gradient over the canopy, and the point-to-point variation of this scaled temperature from its average for all locations was examined for correlation with the point-to-point deviations of canopy view factor. The results indicate independence at all the levels for which temperature was measured.

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Canopy closure has usually been considered a major factor determining forest climate. When a survey of air temperatures[2] in an even-aged pine stand indicated large point-to-point variation of air temperature, it seemed likely that these variations would be closely correlated with local deviations of canopy closure from the stand average. Such was not the case, however.

Not only was the degree of association small, it was also contrary to what would be expected from local energy balance considerations.

The pine stand had an average height of 10 meters (m) and a density of 17 stems/100 m^2. The height of maximum foliage concentration averaged about 7 m.[3]

Canopy cover was calculated from vertical photographs taken at a height of 50 cm above the base of the air temperature profile arrays. The camera lens angle was 45°, covering a square of about 13 m on a side at the height of the foliage maximum. The method of computing canopy cover is described in another Note (Bergen 1974). The variable actually used in the calculations was the skyview factor F, defined as 100 minus the canopy cover.

Air temperature was measured at heights of 1, 2.5, 4.0, 5.6, 7.0, and 8.6 m on one or both of two portable masts, with shielded bead thermistors. Air temperature was also measured at 11.5, 16.5, and 22.5 m on a fixed tower within 30 m of all the mast locations. The masts were located approximately on a grid of points.[2] Masts were actually placed approximately equidistant from the four trees nearest to each point. The air temperature could be expected to be a local maximum or minimum in such locations, while the view factor would obviously be a local maximum. Temperature profiles were measured at intervals of about 15 minutes; masts were left in position from 1 to 3 days.

To compare temperature profiles taken on different days with different above-canopy conditions, we may make the scaling analysis from another paper.[2] Thus $(T - T_h)/(T_a - T_h)$, denoted $\bar{T}'$, where T = the local air temperature, T_h = the temperature at the fixed tower top, and T_a = the temperature at 11.5 m on the

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[2]*Bergen, James D. Spatial variation and scaling problems for vertical air temperature profiles in a pine stand. (Manuscript in preparation at Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado.)*

[3]*Gary, Howard L. Crown structure and vertical distribution of biomass in a lodgepole pine stand. (Manuscript in preparation at Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado.)*

fixed tower, depends only, for any particular point in the stand, on the solar elevation, the cloud cover, and wind direction. To use this relationship for the calculations to follow, only those measurements taken on clear days and within an hour of noon are considered. The wind direction above the canopy in all cases was within 10° of southwesterly.

Data from 17 positions in the stand met these requirements; of these, two were discarded because the vertical photographs were unduly influenced by one or two low-lying branches. Of the remaining 15, 12 consisted of six simultaneous pairs; that is, two profiles made on masts at different locations.

The F measurements for the 40 points in the stand show a distribution not significantly different from normal, as contrasted to the U-shaped distribution which might have been expected if points beneath crowns had been included. The range is 51 to 100 percent.

The relation of canopy closure or equivalent F factor to the vertical temperature profile apparently has not received much direct attention. The most comprehensive relevant study in the literature is that by Gohre and Lutzke (1956), where the vertical temperature profiles measured in a spruce stand and two pine stands of different stem density are compared. They distinguish between "dense" stands, where the only local temperature maximum is found in the crown, and "open" stands, where there is a canopy and stand-floor maximum. If such distinction could be applied to the small-scale variations in a stand, we would anticipate that a local temperature profile would tend toward the "dense" or "cold-floor" type as the F factor decreased, or equivalently that upper canopy temperatures would be negatively correlated with F while subcanopy temperatures would show a positive correlation.

The first prediction is hard to test with the data at hand — only about six of the locations were without a local maximum near the floor. The average F values for the "cold-floor" locations was 71, compared to 66 for the remaining locations, an insignificant difference in terms of the sample size.

The simultaneous pairs of profiles also show no tendency for the profile in the location with the highest F factor to be colder or warmer than the profile at the other location. The sign of the difference alternates evenly between the six pairs.

Using the scaling relation mentioned above, we can calculate the linear correlation over the 15 points for the average values of T' in the upper canopy, lower canopy, and subcanopy space, with the local F. The upper canopy is represented by the temperatures at 8.5 and 7 m, the lower canopy by those at 5.6 and 4.0, and so on. The results are shown in table 1,

Table 1.--Correlation of scaled air temperature measured between trees and vertical skyview factor F

Item	Level		
	Subcanopy	Lower canopy	Upper canopy
Variance of scaled air temperature	1.93	4.60	3.80
Calculated correlation with view factor F	- .56	+ .12	+ .06
90 percent confidence interval for stand correlation	+ .14 - .82	- .22 + .75	+ .47 - .47

together with the 90 percent confidence interval computed, using Fisher's Z distribution (Panofsky and Brier 1958). Since F must have a truncated distribution on physical grounds, however, this interval is probably an overestimate. The corresponding scatter diagram is shown as a composite in figure 1.

As may be seen, we can reject any appreciable positive correlation between the subcanopy air temperatures and local F factor; the most probable value is negative. Nothing can really be said about the situation in the lower canopy. In the upper canopy, there is no support for a negative correlation or the positive correlation to be expected from the subcanopy result.

While these results are discouraging in regard to designing stratified sampling schemes for forest air temperature based on canopy cover, they are welcome insofar as they imply that these two major factors in the canopy energy balance are relatively independent insofar as their point-to-point deviations from the stand average are concerned. Thus such deviations pose no serious objection to computing such quantities as evapotranspiration estimates from stand average canopy cover.

Apparently the factor F does not closely reflect the actual density of foliage above the points considered, or the canopy and subcanopy air motion is sufficient to level out any local temperature differences generated by the uneven radiation field indicated by F.

Literature Cited

Bergen, James D.
1974. Variations of windspeed with canopy cover within a lodgepole pine stand. USDA For. Serv. Res. Note RM-252, 4 p.

Gohre, K., and R. Lutzke.
1956. Der Eingfluss von Bestandesdichte und Strucktur auf das Kleinklima im Walde. Arch. fur Forstwes. 5:387-572.

Panofsky, H. H., and G. W. Brier.
1958. Some applications of statistics to meteorology. 224 p. Pa. State Univ. Press, Univ. Park, Pa.

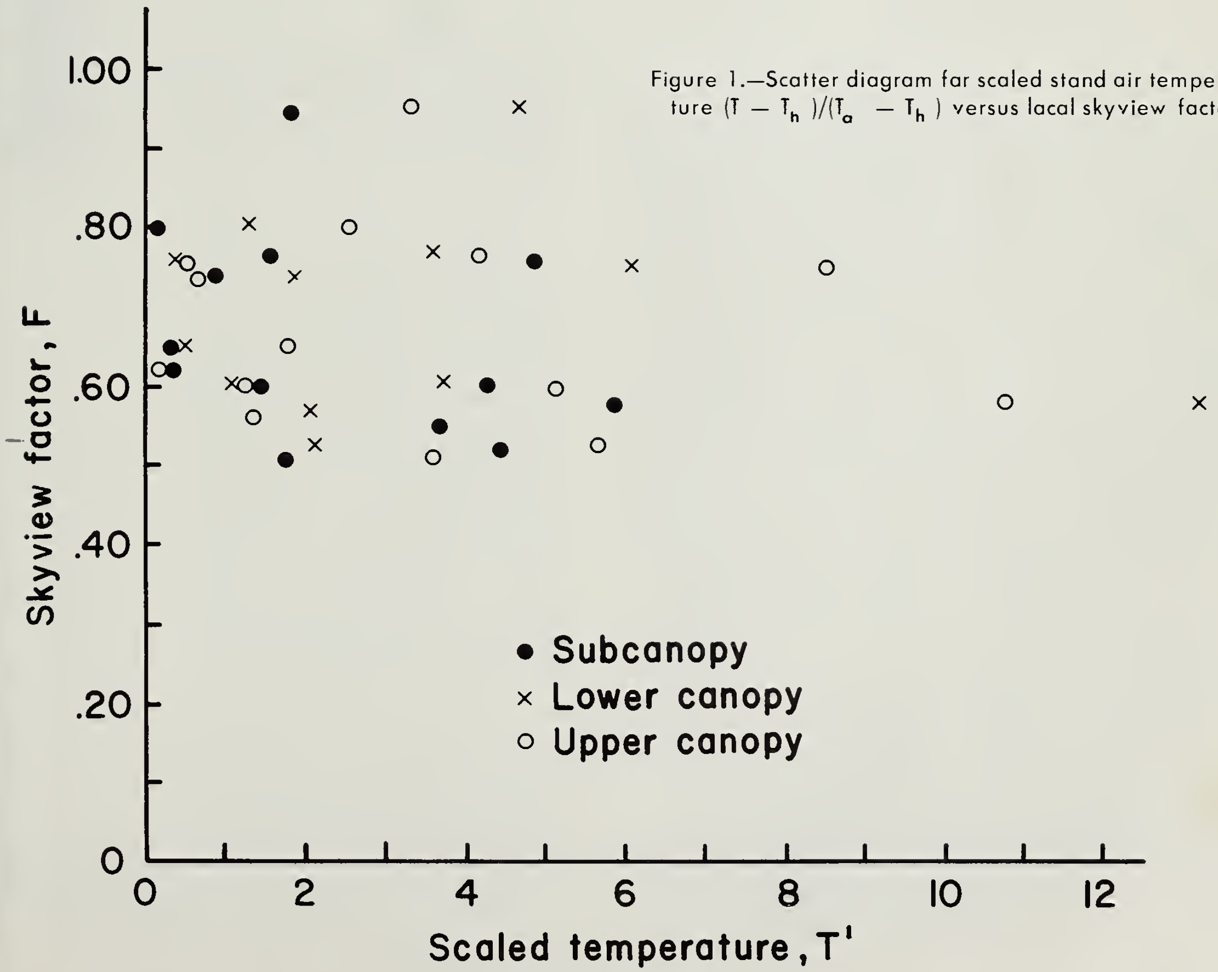

Figure 1.—Scatter diagram for scaled stand air temperature $(T - T_h)/(T_a - T_h)$ versus local skyview factor.

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